

Why phase information is important for diagnosing machinery problems



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Accurate diagnosis of machinery problems requires a complete set of machine vibration information. That information comes from the three primary parts of the data that we can obtain from a vibration signal: direct amplitude, frequency, and, when there are two signals, phase. Relative phase is the timing relationship between two vibration signals, while absolute phase compares a vibration signal to a once-per-turn reference pulse. The Keyphasor[®] signal is a once-per-turn voltage pulse provided by a transducer (normally a proximity probe). The Keyphasor signal is used by monitoring, diagnostic, and management systems to generate filtered vibration amplitude, phase lag, speed, and a variety of other information. Keyphasor-generated information can help the Operator or Machinery Specialist identify developing machine problems or distinguish serious problems from less serious ones. The Keyphasor signal is used to generate more than one third of the information regarding the condition of the machine. Phase (relative and absolute) is a critical part of this information. Without phase information, overall machine condition and machine

faults would often be very difficult, if not impossible, to diagnose.

Why is phase important?

Phase information can be used to detect subtle changes to the machinery that may otherwise go unnoticed. Listed below are a few of the many phase angle applications:

- Trending for Acceptance Regions
- Shaft crack detection
- Rub detection
- Shaft balancing
- Shaft/structural resonance detection
- Shaft mode shape
- Location of a fluid-induced instability

Trending amplitude and phase information can provide early shaft crack detection and alert the Operators to other possible machine problems. Rub conditions can be detected with the use of phase presented in steady state polar plots. Machinery Specialists use phase extensively in their analysis to confirm suspected machine problems.

Trending phase information

The Acceptance Region trend format is a polar or rectangular coordinate plot (Figure 1) produced by sampling vibration vector components as a function of time. Acceptance Region describes a range of vector movements considered acceptable for normal machine

operation. Such trends should be maintained for 1X, 2X, and slow roll vectors. Any movement of these vectors outside of the acceptance boundaries should be viewed with suspicion. Correlation of the 1X and 2X vectors with load, field current steam conditions and other process parameters is used to determine whether vector shifts are caused by a shaft crack or by other factors. Changes in the slow roll vector can be caused by shaft crack and rotor bow.

Shaft crack detection

The Amplitude and PHase versus Time plot (APHT plot) (Figure 2) shows that 1X vibration amplitude is continually increasing. Note that the increase in vibration amplitude level is only half of the picture. The continual change in phase shown in the plot reveals critical information regarding

POINT: BRG #1 X /45°R 1X UNCOMP 2.54 Z0° 10JUN1999@14:50:00
 From 21APR1999 05:30:00 To 29JUN1999 13:40:00 Steady State

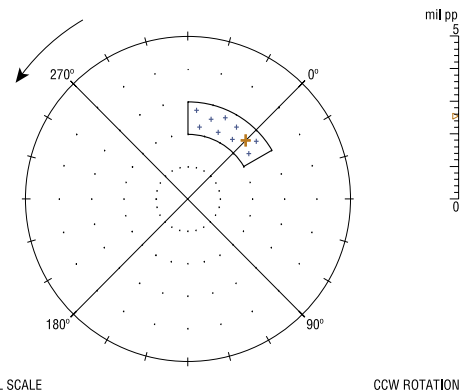


Figure 1. Data Manager[®] Acceptance Region plot of 1X or 2X vibration vectors.

the condition of the machine. The phase information reduces the possible number of machine faults to a family of possibilities. Two of the main shaft crack symptoms are 1X vibration amplitude change and phase shift. With a knowledge of other symptoms and a detailed history of the machine, you can analyze other plots and process information to reduce the number of possible machine faults. Without the phase information in this trend plot, the possible seriousness of the machine condition could be overlooked.

Rub detection

Absolute and relative phase are useful for detecting rub conditions. Changes in steady state phase, reverse components in orbits or full spectrum plots, and abnormal rate of change of phase during transient conditions can be indicators of a rub condition. Figure 3 shows a steady state polar plot trend during a rub condition. This polar plot shows the continual phase change due to thermal bow modification to the heavy spot, due to a light seal rub. Without phase information, this would only show as a variation in 1X vibration amplitude, and it would be very difficult for the

Machinery Specialist to determine the root cause of the generally increasing vibration amplitude. Phase information considerably reduces the list of possible machine malfunctions.

Shaft balancing

Absolute phase angle information is crucial to proper rotor balancing. Phase information is used to compensate for non-dynamic influences (slow roll vector) and to establish influence vectors for individual machines. Once slow roll, unbalance response, and influence vectors are established, it is possible for the Machinery Specialist to balance a rotor in a minimal number of runs.

Shaft mode shape

By comparing the absolute or relative phase between different measurement planes, the rotor's mode shape can be determined. In the simplest case, we compare the phase of a probe signal at the inboard end of the machine to that of a probe signal with the same angular orientation at the outboard end of a machine (Figure 4). If the two signals are in phase, the rotor is operating in the translational (bow) mode. If the signals are out of phase, the rotor is oper-

ating in the pivotal mode. Depending on rotor mass, system stiffness, and rotor speed, higher modes of operation can be attained. If more measurement planes exist between the inboard and outboard ends, a better representation of the mode shape can be determined (Figure 5). It's important to realize that you could not determine the rotor's mode shape if you were looking at the amplitude only or just the frequency of the vibration signals. Mode identification probes can also be useful to determine whether a resonance is structural or rotor related. Shaft mode shape information can also be used in determining balancing strategy.

Location of fluid-induced instability

Differential phase is a specific type of relative phase measurement that can be used in determining the source of a fluid-induced instability. The transducers (which, for best results, should be shaft relative) must be in different planes along the rotor and at the same angular orientation. The vibration should be filtered to the frequency of the instability vibration. The phase lag increases (Figure 6) as the axial distance between the instability source and the measurement planes increases.

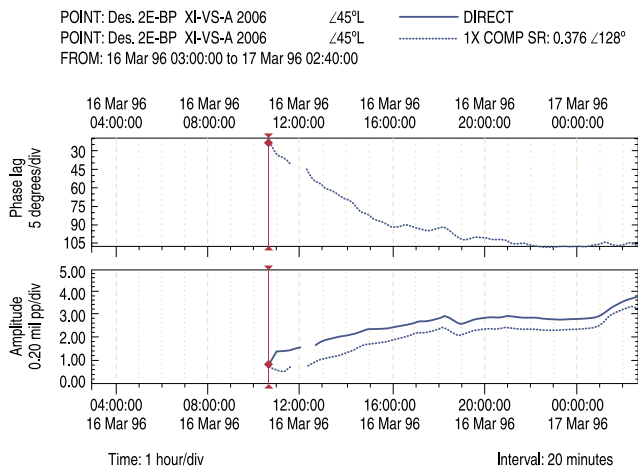


Figure 2. Amplitude and PHase versus Time (APHT) trend plot of 1X vibration due to shaft crack.

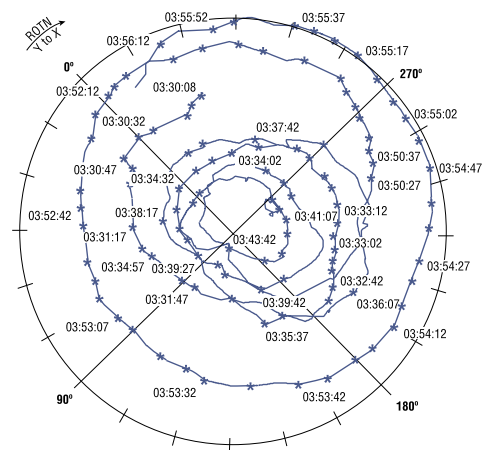


Figure 3. Polar vibration trend plot of steady state vibration due to a seal rub.

Conclusions

Phase information is important for the Operators and Machinery Specialists. Trending of startup, shutdown, and steady state data provides critical information for machinery management. The absence of phase information leaves a large gap in the usefulness of this information. Changes in phase can alert the operator before costly machine damage occurs. Bently Nevada's 3500 Machinery Protection System, the Trendmaster® 2000 System, and Data Manager® 2000 System can alert the operator to changes in 1X and 2X amplitude and phase. These Bently Nevada systems were designed to present information in a way that is easy for Operators and Machinery Specialists to retrieve and understand.

Direct amplitude, frequency, and phase information are important in machinery management and diagnostics. Lack of phase information can not only lead to an inability to diagnose a machine problem, but can lead to an incorrect diagnosis. That is why Bently Nevada and the American Petroleum Institute, in its specifications for machinery protection systems, recommend installing a Keyphasor and redundant Keyphasor transducers for phase measurement.

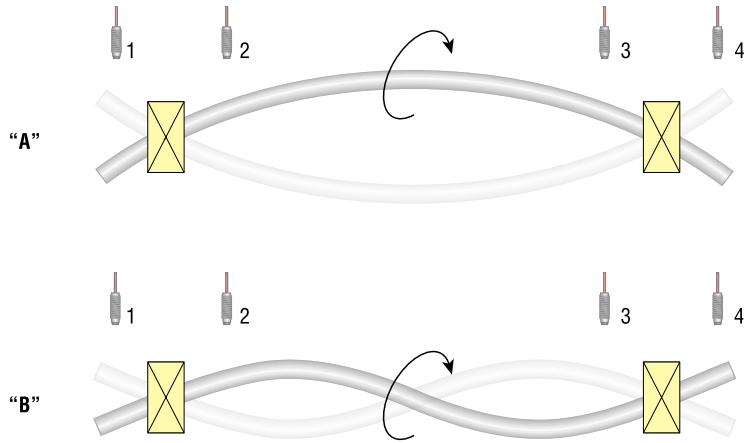


Figure 4. Vibration mode shape of rotor can be determined by comparing phase of vibration at each end of the machine. Poor selection of probe location can lead to ambiguity about operating mode of rotor.

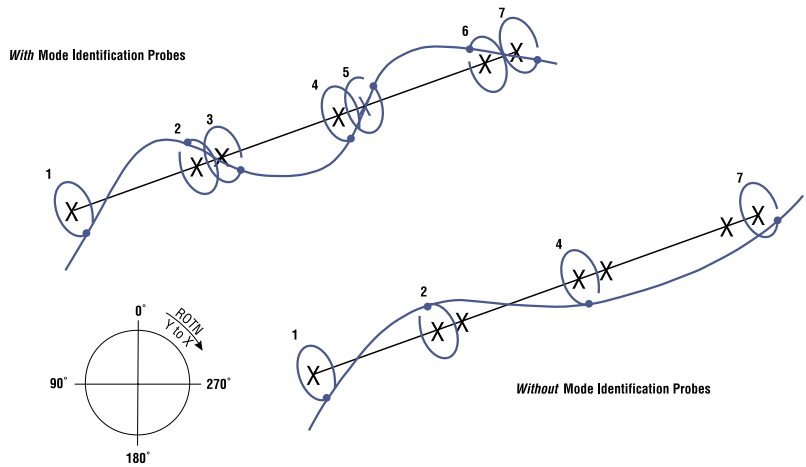


Figure 5. Too few vibration probes can provide insufficient phase and amplitude data about the true vibration mode shape of the rotor on a complex machine train.

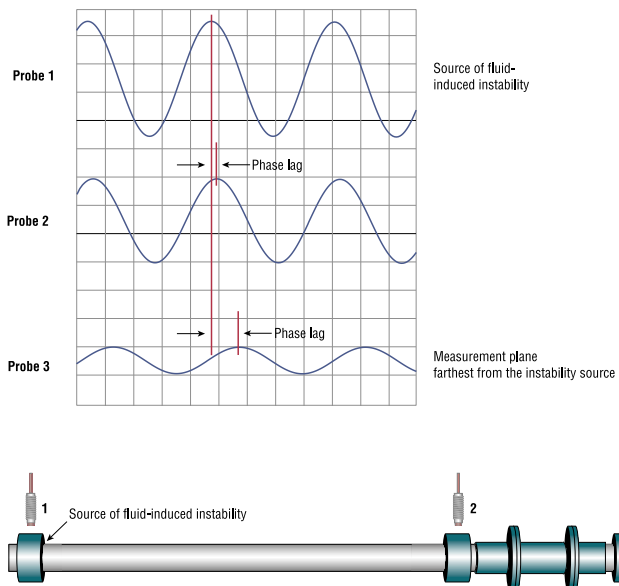


Figure 6. Phase lag of the fluid-induced instability vibration signal increases with distance from the source of the instability.